UNIVERSITI PUTRA MALAYSIA

GIS-BASED SUPPORT SYSTEM FOR TACTICAL TIMBER HARVEST PLANNING: DESIGN AND DEVELOPMENT

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By

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Thesis Submitted in Fulfilment of the Requirements for the Degree of Doctor of Philosophy in the Faculty of Forestry Universiti Putra Malaysia

August 2000

Abstract of thesis presented to the Senate of the Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy.

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Faculty: Forestry

The high costs of timber harvesting and forest road construction warrant extensive planning of harvest blocks and forest road network layout. The integration of these efforts in the overall management decision making process will result in more efficient timber harvesting operations. Traditionally, harvest planners have relied in personal experience to guide them through this planning process. However, the harvest planner may not be able to utilize these traditional planning techniques when dealing with large areas due to the increased data demands of the planning process. This study describes a terrain classification method and the development of a Decision Support System (DSS) known as "MERANTI" for short-term harvest planning that combines the data handling, storage, and retrieval advantages of a geographic information system with the decision modelling capabilities of heuristic programming.

The terrain classification system characterizes the terrain of forested areas in eastern part of Malaysia in terms of slope and ground conditions. The DSS consists of three major components: the geographic information system, a library of decision models, and a graphics interface. The geographic information system contains information on timber volume, roads and the terrain classification developed as a part of this study. The model library consists of three decision models: a heuristic programming to select blocks for harvest and a minimum spanning tree/shortest path module to determine the location of roads to access harvested blocks. The graphics interface provides a linking mechanism between the geographic information system, the decision model, and the harvest planner.

The prototype spatial decision support system (MERANTI) developed in this study provide the harvest planner with an efficient means of evaluating the large amount of data required for automatically selecting blocks for harvest and determining preliminary forest road locations. The results demonstrated that by using "MERANTI" decision support tools during a timber harvest planning process, the effectiveness of decision making could be improved. The findings of the study will help refine the tropical hill Dipterocarp timber harvesting system and planning and could provide guidelines for future GIS-based support system development.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah.

SISTEM SOKONGAN BERDASARKAN SISTEM MAKLUMAT GEOGRAFI BAGI PERANCANGAN PENUAIAN KAYU BALAK TAKTIKAL: REKABENTUK DAN PEMBANGUNAN

Oleh

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Oktober 2000

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Kos yang tinggi dalam penuaian hutan dan pembinaan rangkaian jalan hutan menyebabkan perlunya satu perancangan blok penuaian dan reka-letak halaman rangkaian jalan hutan yang rapi. Penyatuan usaha-usaha ini dalam proses membuat keputusan pihak pengurusan akan menghasilkan operasi penuaian yang lebih efisyen. Secara tradisinya para perancang penuaian bergantung kepada pengalaman peribadi sebagai panduan dalam peroses perancangan ini. Walaubagaimanapun, perancang tuaian tidak akan dapat menggunakan teknik tradisi ini sekiranya berhadapan dengan kawasan yang luas kerana proses perancangan hutan memerlukan permintaan data yang tinggi. Kajian ini menerangkan satu teknik klasifikasi dan pembangunan Sistem Sokongan Keputusan (DSS) yang dikenali sebagai "MERANTI" untuk memilih secara automatik blok penuaian dan menentukan perancangan awal lokasi rangkaian jalan hutan menggunakan Sistem Maklumat Geografi (GIS) yang sepadu dan pencarian kerangka kerja kemampuan pengiraan telah dibentuk.

Sistem klasifikasi terrain kawasan hutan menunjukkan sifat terrain sesuatu kawasan hutan di timur Malaysia dari aspek kecerunan dan keadaan tanah. Sistem bantuan berasaskan GIS ini mengandungi maklumat tentang blok penuaian kayu, kawasan, kandungan isi per blok, kecerunan, keadaan tanah, spesis kayu, jalan-jalan sedia ada dan pembangunan program sepadu untuk memilih blok tuaian dan jarak minima pokok bagi menentukan lokasi jalan masuk ke blok penuaian. Tambahan pula grafik telah digunakan bagi menghubungkan GIS dengan model keputusan dan perancang penuaian.

Prototaip Sistem Sokongan Keputusan (MERANTI) yang telah dibangunkan dalam kajian ini dapat membantu perancang tuaian dengan cara menilai data yang banyak untuk memilih blok penuaian secara otomatik dan menentukan lokasi awal jalan hutan. Hasilnya membuktikan bahawa rekabentuk MERANTI adalah satu konsep yang baik. Dengan menggunakan peralatan bantuan membuat keputusan seperti MERANTI dalam proses merancang penuaian kayu balak, keberkesanan proses membuat keputusan dapat dipertingkatkan. Hasil dari kajian ini akan membantu memperbaiki sistem dan menyediakan garispanduan dalam pembentukan sistem bantuan berasaskan GIS di masa akan datang.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my heart-felt gratitude to my major supervisor Capt. Prof. Dr. Kamaruzaman Jusoff, for his guidance, encouragement, support and friendship. I thank him for his input in this study, for his patience and for the knowledge I gained from his comments and suggestions. I would like to thank my supervisory committee members, Prof. Dato' Dr. Nik Muhamad Abd. Majid, and Assoc. Prof. Dr. Azizi Muda for their constructive criticism that substantially improved this study.

I would like to acknowledge Mr. Idi Fulayi a Ph.D. student from the Department of Computer Sciences, Universiti Putra Malaysia and Mr. Mohamad Salah, lecturer from the same department, for their patience, diligence and invaluable help in debugging the computer program. I am sincerely thankful for their assistance to overcome inherent weaknesses in FORTRAN and PROLOG computer languages.

I would also like to acknowledge Mr. Jimat Bolhasan from the Malaysian Centre for Remote Sensing (MACRES) for his assistance. I thank him for making GIS with all its complication and intrigue, an easy topic. I would also like to extend my appreciation to Prof. Dr. Ragnar Oborn and Prof. Dr. Edward Robak, from the Faculty of Forestry and Environmental Management, University of New Brunswick, Canada, who provided a wealth of information about the practical aspects of decision support systems. I must also thank Mr. Jaywyn Yeo for his computer technical support and Mr. Aziz Daud from SSM Advanced

Technology Sdn. Bhd., for sharing with me his knowledge about data conversion and scanning procedures.

Special appreciation also goes to the Brazilian Government, CAPES (Post-Graduate Federal Agency) and Amazonas Institute of Technology for their financial support for me to complete the study. I also acknowledge the financial support provided by Prof. Dr. Kamaruzaman's IRPA grant from Malaysian Ministry of Science Technology and Environment in the field data collection.

Finally, all I have accomplished would not have been possible without the consistent support of my family. To my wife Virginia and daughters Penelope and Ariadne who not only endured without protest the loneliness while I prepared my dissertation, but also provided their loving encouragement throughout this long study.

I certify that an Examination Committee met on 2nd August 2000 to conduct the final examination of Judibal Carvalho Cabral on his Doctor of Philosophy thesis entitled "GIS-Based Support System for Tactical Timber Harvest Planning: Design and Development" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

(JUDIBAL CARVALHO CABRAL)

Date: 16 March 2000

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CHAPTER I

INTRODUCTION

Background to the Study

Over the last two decades, concern and recognition of economic and environmental problems with timber harvesting in Malaysia have emerged. In many states legislation has attempted to overcome some of these problems by establishing a framework for forest management. In most instances this legislation has requested forest companies to submit harvesting plans at regular intervals, enabling government agencies to better monitor and regulate timber harvesting. Many forest industries are integrating public concerns and environmental issues into their planning process. Because of the pressure on them, forest industries are learning how to manage their concession area to meet both the economic and environmental objectives. To ensure that the timber harvesting plan be implemented, harvest blocks established on the forest must be selected in accordance with the objectives of the harvest planning. If they do not, the assumptions of the harvesting plan may not hold. Future volume to be harvested might be jeopardized by inappropriate harvest block selection.

An examination of the literature concerning the applications of operational techniques to harvest planning indicates that these applications are normally classified according to the length of the planning period. Usually, strategic harvest plan is a long-term plan, which typically addresses the questions of what to do and when to do, but the question of where to do is deferred, more appropriately addressed at the tactical level.

Operations research techniques have been used extensively in the past to assist in planning. However, applications of these models have been limited in harvest planning because of the difficulty encountered by planners in selecting the appropriate model. The lack of familiarity with the data requirements and inherent assumptions incorporated in some of these mathematical techniques may result in the choice of inappropriate models. Even if the correct model is selected, the large data requirements for harvest planning may preclude the model's use by management personnel. In fact, Robak's (1985) survey of operations managers in the Canadian forest products industry indicated that many of these mathematical programming models were considered to be "operationally unworkable" because of the large amount of data required.

Geographic information systems have been used by the forest sector primarily for the storage of inventory and ownership information. While GIS systems have the potential to aid in the harvest planning process, very few forest products companies have used GIS systems for purposes other than producing maps and maintaining and/or updating databases.

A logical means of reducing the complexity of the harvest planning process is to devise a method of combining the data storage and retrieval capabilities of the GIS with the efficiencies of mathematical programming models to assist the harvest planner in his complex and changing planning environment. This is not a new idea, but recent financial pressures on forest products companies has refocused the industry's attention on this research area. A methodology that could adequately incorporate topography, soil, timber resources and environmental aspects in timber planning in the decision-making process would help forest planners obtain optimum use of the forest resource. The tactical harvest planning described here has been designed to plan timber harvesting using available timber resources, areas to be selected for harvesting, and minimum road construction to access areas scheduled for harvest in the form of terrain features.

Objectives

The primary objective of this study was to develop a framework for spatial decision support system to assist timber harvesting planners and managers in determining areas to be harvested and preliminary road locations on a tract of forest land.

The objectives were achieved by:

1. Developing a model to estimate new access road construction requirements (approximate location of new roads) considering slope and ground conditions to access harvest blocks selected for harvesting.

2. Developing a tactical harvest block system for finding feasible, realistic solutions to block selection problem in the presence of environmental constraints and volume demands.

3. Providing a method for the integration of the above two systems into a GIS-based support system for timber harvest planning and preliminary road location.

The first stage of this study provides a model on preliminary road locations for timber harvesting planners. This step was accomplished through mathematical calculations and interface development.

The second stage of this study focuses on utilizing the spatial information in a geo-referenced image base, the spatial information in a harvest block database, and a tactical harvest block simulation model in a model-base to aid a short term (five years planning horizon) timber harvest planning. This scheme was achieved through the development of several sub-systems:

1. A forest database sub-system to maintain the block database with the capability of updating, searching, editing, reporting block data, and communicating block attributes with graphical display element.

2. A harvest block model base sub-system to manage harvest blocks for timber harvesting projection based on a user defined scheme over a defined time period.

3. Integrating the above sub-systems and access road location model into a user-friendly GIS-based decision support that displays results in graphic format, and also generates a summarized report of selected decisions.

Organization of the Study Report

This thesis is divided into five chapters. Chapter one describes objectives of the study. Chapter two provides general background to two primary topics of concern: forest harvesting planning and decision support tools related to the development of spatial decision support systems (SDSS). Two important techniques used in this project, heuristic programming and geographic information system are reviewed. Chapter three gives a general overview of the structure of the timber harvesting plan program, and provides a conceptual framework of a SDSS for tactical harvesting plan and access road location. Chapter four provides results of input data used and discussed the prototype SDSS (MERANTI) that was developed, based on the framework described in chapter three. Chapter five summarizes the research by reporting conclusions and contributions of the project, and suggested areas for further study.

CHAPTER II

LITERATURE REVIEW

Spatial Decision Support Systems

Spatial Decision Support Systems (SDSS), as the name indicates, are essentially decision support systems (DSS). In order to understand how these systems function as decision support tools for a decision maker, a brief review of decision making and information systems is presented, characteristics of a typical DSS are derived, and application of DSS about timber harvesting plan in order to assist the forest manager is described. A summarized description of geographic information systems (GIS), its application on forest management, and a spatial domain of SDSS is introduced so that the impact of spatial information on managerial decision making can be understood. Finally, the chapter provides a theoretical framework for the SDSS development.

The Dilemmas of Decision Making

Decision making, defined very simply, is the process of making a conscious choice among several alternatives (Mumford, 1991). Today's decision making increasingly requires a good knowledge of the organizational environment, which is becoming more and more complex and volatile. It requires an understanding of those factors which are most critical to organizational success and failure. The factors are not always easy to identify. Usually the number of options available is greater than the number of alternatives that are examined by the decision makers and there may be options they are not even aware. Decision makers need to constantly monitor their environments in order to recognize events that require fundamental or marginal changes.

Decision making is always a political process (Mumford, 1991). It has the added problem that it often involves different groups with different interests and degrees of influence. The results of such decision making can be to compromise, to fudge, to make no decision, or fail to implement a decision. Effective decision making requires knowledge and skills. Political knowledge of where power is located within the organization may be as important as an understanding of the problem. Similarly, skills in persuasion may be as important as rational argument. Decision makers not only have to convince their peers of the correctness of a particular course of action, they also have to convince the public and non-participating colleagues. It is very common for major conflicts of interest to arise. If decision makers are unable to make their views known, the result can be an inability to get a solution to a problem successfully implemented.

Good decision making is often difficult and suffers from many constraints. Some of these constraints can be the result of knowledge limitation, poor communication, or overloaded information. A characteristic of today's decision is that it is unstructured with the dimensions of the problem poorly or not fully understood. This makes the use of a theory as a decision aid difficult unless the theory is of a very general nature. Human intuition and judgement may probe to be more useful than knowledge and experience (Keen and Scott-Morton, 1981). The best decision maker may be the manager who can recognize the complexity of the decision making environment and think in a multidimensional and integrative manner.

Modern information technology does change the nature of decision making to some extent. It uses documentation rather than observation as its data source. It reduces the scope for human judgement and intuition, and it can greatly speed-up the decision making process. As a result, the technology can lead to a more consistent and predictable decision. However, it is important to note that information technology is closely dependent on the development of computer technology, and that computers are machines. Computers are not used to replace human beings for decision making. Rather, they are used to do what they are good at - assisting and advising. It is the human being who always has to carry out the difficult part of the decision making task - helping people understand the problem, agree on a solution, and implement this solution successfully.

The Role of Information Systems

In the early 1980s, several articles explored an intuitive dichotomy labeled Type I and Type II information activities (Panko and Sprague, 1982; 1984). Type I information work consists of a large volume of low cost and low value transactions. It is performed according to a well-defined procedure with an emphasis on efficiency, and it uses data in a relatively well structured form. By contrast, Type II information work consists of fewer, but more costly and more valuable transactions for which there exists no pre-defined procedures, and that deals with unstructured and often ambiguous data. Figuring out how to do the work is the most important part of the job. The output, and therefore the efficiency, cannot easily be measured because Type II work involves problem solving and goal attainment. It is clear that the majority use of information systems in the past has been for the support of Type I tasks, since they are the easiest and most natural to use a computer to support process driven works. Therefore, the real challenge of future information system is to support Type II tasks.

In a relatively stable environment, computers have proven to be quite effective in applications of information technology. They have made organizations much more efficient by performing more of primary Type I work faster and at lower cost. But those systems alone no longer provide the necessary competitive advantage. Good decision making today depends on a comprehensive understanding of the environment in which the problem is located. However, with the increased complexity of a decision environment, it is difficult for a Type II decision maker to use the tools which have been proven better for doing Type I tasks. It has been realized that human judgment is hardly automated even with more and more sophisticated technologies becoming available and affordable. Under these circumstances, information technology is directed towards improving human performance.